A Non-mainstream Viewpoint on the Apparent Superluminal Phenomena in AGN jet

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ABSTRACT

The material around an AGN jet is generally assumed to be plasma which of refractive index is 1. In this letter, we propose a non-mainstream viewpoint which considers that the equivalent refractive index of the surrounding medium in an AGN jet is not equal to 1. Applying this viewpoint to the beaming model of AGN jet, we could get a lower true velocity and a higher Doppler factor than the classic model, which may reduce the singularity of AGN and its jet. At present, this letter contains only the germ of an idea and the physical meaning of the equivalent refractive index needs to be further studied.

Subject headings: galaxies: active — galaxies: jets

Concerning the apparent superlunimal motion, the most popular and classic viewpoint is the relativistic beaming model (Rees 1966). The Fig. S.6 in Ribicki & Lightman (2004) showed the simple geometry scenario of emission for a moving source, the observed transverse velocity of separation of a blob relative to the speed of light c (in this paper, all velocities are at c as a unit) is :

$$\beta_a = \frac{\beta sin\theta}{1 - \beta cos\theta}, \tag{1}$$

where β is the true velocity, and θ is the angle to the line of sight. The corresponding Doppler factor δ (considering the effect of redshift) is :

$$\delta = [\Gamma(1 + z)(1 - \beta cos\theta)]^{-1}, \tag{2}$$

where $\Gamma = (1 - \beta^2)^{-1/2}$ is the Lorentz factor, z is the redshift of this AGN.

For the 3C 273 jet ($z = 0.158$), VLBI observations have detected apparent superluminal motions in the parsec-scale jet with apparent velocities $6 \sim 10$ (e.g., Unwin et al. 1985). We assume the apparent velocity is 8, and the angle to the line of sight is $10°$. Then, based on the formula (1) and (2), we could obtain the Doppler factor $\delta \sim 5$, and the true velocity $\sim$

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0.994 (Lorentz factor $\Gamma \sim 9$) which means the velocity of the 'ordinary' matter in the AGN jet is extremely close to the speed of light (this requires a very high energy and an effective acceleration mechanism, which is unimaginable on Earth).

The formula (1) & (2) actually imply that the refractive index of the medium surrounding a blob in the AGN jet is equal to 1, which is actually a hypothesis. In the following, we will consider another scheme.

We assume that the unknown transparent medium surrounding a blob is uniform, stationary relative to the AGN core, and the equivalent refractive index is n which is not equal to 1.

Then we could apply the similar derivation like Ribicki & Lightman (2004) and get the 'new' (modified) apparent velocity & Doppler formula :

$$\beta_a = \frac{\beta sin\theta}{1 - n\beta cos\theta}, \tag{3}$$

$$\delta = [\Gamma(1+z)(1 - n\beta cos\theta)]^{-1}, \tag{4}$$

We apply the formula (3) & (4) to the 3C 273 jet (we assume that $\beta_a = 8$, $\theta = 10^{\circ}$, $n = 10^4$) and obtain the Doppler factor $\delta \sim 4 \times 10^5$, the true velocity ~ 0.0001 (Lorentz factor $\Gamma \sim 1$). For synchrotron emission, the observed fluxes are proportional to $\delta^{3+\alpha}$ (Dermer 1995, α is the spectral index). If $\alpha = \alpha_{radio} \sim 0.8$ (e.g., Stawarz 2004) and $\delta \sim 4 \times 10^5$, then the observed fluxes of the 3C 273 jet are 2×10^{21} times the local ones, which may reduce the singularity of AGN jet. The high observed luminosity of AGN may also be attributed to the unknown surrounding medium which of the equivalent refractive index is not equal to 1. The equivalent refractive index may be related to the gravitational effect or optical properties of the surrounding medium. The physical meaning of the equivalent refractive index needs to be further studied.

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